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Stability and Lifetime of Small Molecule based Organic Solar Cells using Bathocuproine (BCP) and Zinc Oxide (ZnO) as Electron Transport Layers

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Introduction

- Performance of inverted small molecule Organic Solar Cells (OSCs) composed of Tetraphenyldibenzoperiflanthene (DBP) as donor and Fullerene (C_{70}) as acceptor, fabricated by Organic Molecular Beam Deposition (OMBD) technique
- Performance and lifetime of OSCs based on OMBD evaporated Bathocuproine (BCP) and solution processed Zinc Oxide (ZnO) as Electron Transport Layers (ETL) was investigated
- Additionally, the effects of the Exciton Blocking Layer N,N'-di-1-naphthalenyl-N,N'-diphenyl-[1,1':4',1'':4'',1'''-quaterphenyl]-4,4'''-diamine (4P-NPD) on performance, stability and lifetimes of the solar cells was investigated.

OSCs with BCP and ZnO as Electron Transport Layer (ETL)

- Experimental

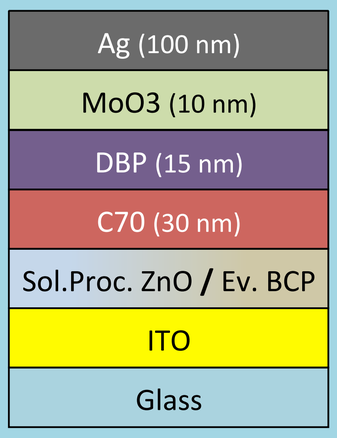

Figure 1: Fabricated inverted OSC stack with BCP or ZnO layers as ETL

- DBP/C_{70} based inverted OSCs were fabricated by Organic Molecular Beam Deposition (OMBD) technique
- Two different ETL materials used: ZnO or BCP
- Commercial ZnO ink layer (30 nm) was spin coated while BCP (5 nm) was fabricated using OMBD technique

- Results

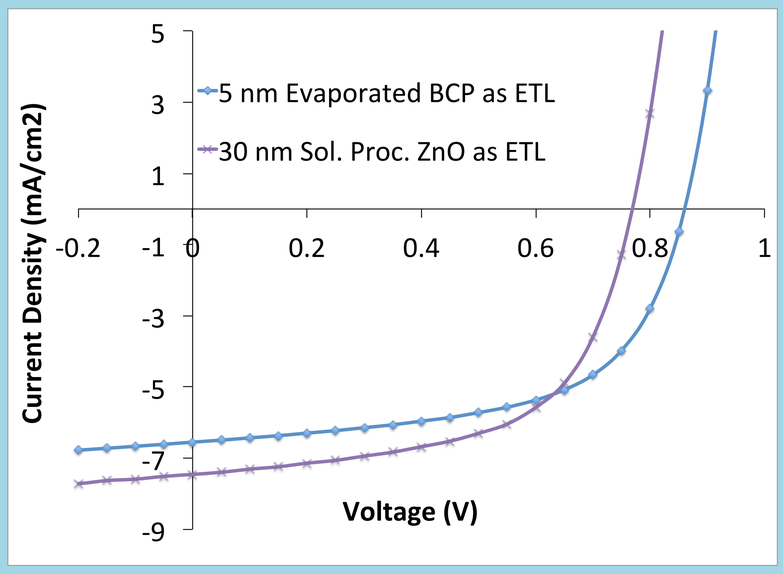

Figure 2: JV characteristics of OSCs with BCP and ZnO layers as ETL

Electron Transport Layer	V_{OC} (mV)	J_{SC} (mA/cm^2)	Fill Factor (%)	PCE (%)
30 nm ZnO	766	**7.58 ± 0.10**	59	3.40 ± 0.04
5 nm BCP	**860**	6.55 ± 0.22	59	3.30 ± 0.07

Table 1: Performance parameters of OSCs with BCP and ZnO layers as ETL

- ZnO based OSCs better in terms of J_{SC} than BCP based OSCs and have slightly higher PCE compared to OSCs based on BCP
- While BCP based OSCs show significantly higher V_{OC} compared to that of OSCs based on ZnO ETL

4P-NPD as Exciton Blocking Layer (EBL)[1]

- Experimental

- Thin films of 4P-NPD with thicknesses of 0.7, 1 and 5 nm were investigated as potential EBL for in inverted OSCs.

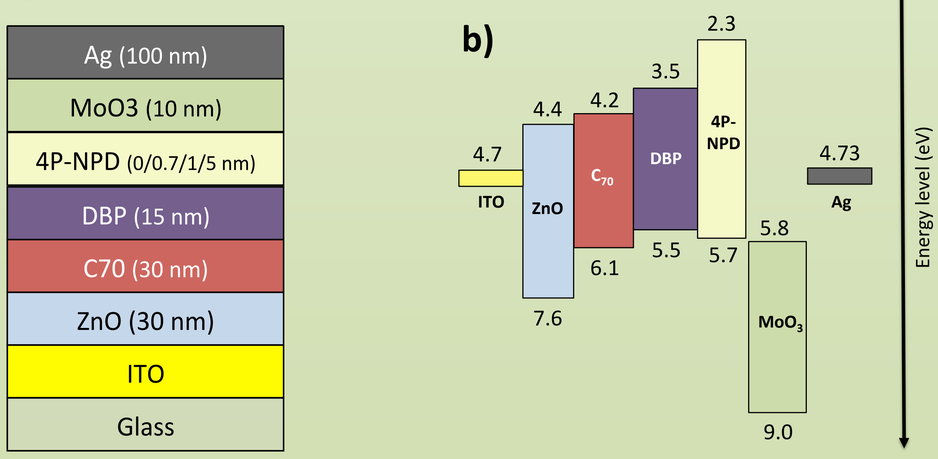

Figure 3: a) layers stack and **b)** energy level diagram of OSCs fabricated with different thicknesses of 4P-NPD as EBL

- Results

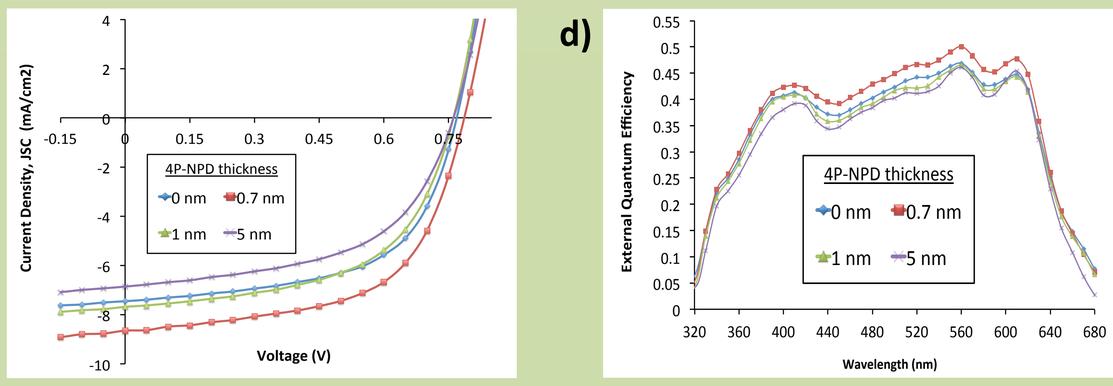

Figure 3: c) JV characteristics and **d)** EQE results of OSCs fabricated with different thicknesses of 4P-NPD as EBL

4P-NPD thickness (nm)	V_{OC} (mV)	J_{SC} (mA/cm^2)	Fill Factor (%)	PCE (%)
0	766	7.58 ± 0.10	59	3.40 ± 0.04
0.7	**785**	**8.60 ± 0.29**	**59**	**3.97 ± 0.13**
1	759	7.69 ± 0.28	56	3.23 ± 0.12
5	760	6.97 ± 0.26	54	2.87 ± 0.10

Table 2: Performance parameters of OSCs with 4P-NPD as EBL

- 0.7 nm 4P-NPD as EBL results in increased J_{SC} and PCE by approx. 13 % and 16 % respectively
- However, increasing the thickness of 4P-NPD EBL higher than 0.7 nm leads to a decrease in performance due to loss mechanisms arising from a small HOMO misalignment, increased series resistance and modified optical absorption profiles[1]

Outlook: OSC lifetime measurement

- JV characteristics of non-encapsulated OSCs with BCP and ZnO as ETL were measured repeatedly in air to characterize OSC lifetime
- Measurements were taken by keeping OSCs in the dark and illuminating them briefly after every 2 min under the irradiation of 100 mW/cm^2 to measure JV characteristics under light

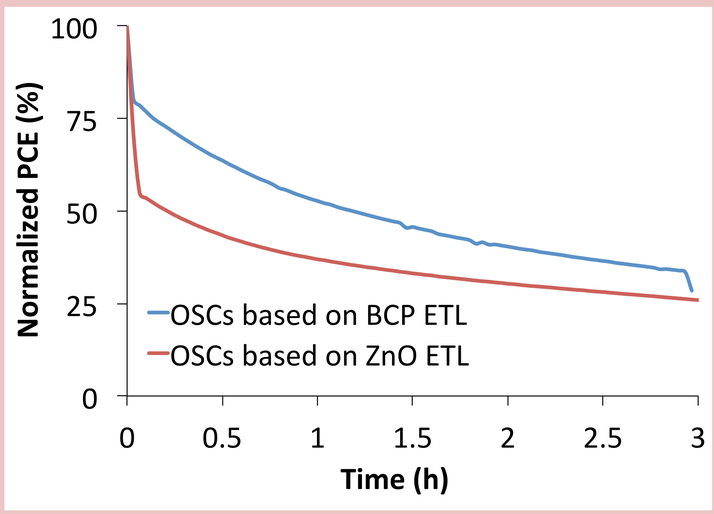

Figure 4: Initial lifetime measurements of OSCs based on BCP and ZnO ETL

- Initial measurements show faster degradation in inverted OSCs based on ZnO ETL

Work in progress..

To measure lifetime of OSCs with different encapsulation techniques and under different accelerated lifetime test conditions

References

[1] B. R. Patil, Y. Liu, T. Qamar, H. G. Rubahn, M. Madsen, "4P-NPD ultra thin-films incorporated as efficient exciton-blocking layers in inverted DBP/C_{70} based organic solar cells " - *submitted in October 2016.*

Acknowledgement

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